An investigation on microstructure and properties of dissimilar welded Inconel 625 and SUS 304 using high-power CO₂ laser

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Abstract Microstructure and properties of laser deep penetration welded Inconel 625 nickel-based alloys and SUS304 stainless steel were investigated. Weld microstructures, room temperature tensile properties and stress rupture properties, impact toughness, and hardness of dissimilar welded joints were evaluated. The experimental results showed that the microstructure of fusion zone near the fusion line in the SUS304 side was mainly cellular, whereas that near the fusion line in the Inconel 625 was predominantly columnar dendrites. Laves phases were precipitated at the grain boundary of cellular and in the interdendritic regions of fusion zone in the different form. The white transition layer was generated, and the signification change of concentrations was occurred at the fusion boundary between weld metal and SUS304. The microstructure at the fusion boundary between weld metal and Inconel 625 was characterized by dendritic boundary melting and thickening and accompanied with a lot of Laves phases precipitated in the interdendritic regions. The tensile strength tests indicated that the dissimilar butt joints ruptured in the fusion zone. The toughness of dissimilar weld metal was declined sharply compared to the two base metals. Fractographic analysis revealed that segregation of Nb and Mo in the interdendritic regions deteriorated the tensile strength and toughness of laser dissimilar weld metal. The corrosion resistance of weld metal was higher than that of SUS304 as a considerable amount of Mo elements in the weld metal inhibiting the generation and development of pitting corrosion.

Keywords Laser welding · Dissimilar weld metal · Laves phases · Fusion boundary · Mechanical properties · Corrosion

1 Introduction

Nickel-based superalloy Inconel 625 is developed as a solid solution strengthened alloy containing relatively high levels of chromium, molybdenum, iron, and niobium. As its high creep strength, excellent fatigue strength, available processability, and well corrosion resistance, Inconel 625 nickel-based superalloy has been broadly utilized in gas turbines for combustion cans and ducts as well as industrial furnace components, chemical power plants, marine systems, and many other fields where high temperature corrosion resistance is generally required and important [1–3]. SUS304 stainless steel, as a common austenite stainless steel, is widely used in petroleum, chemical, and metallurgical industries because of its well toughness, easy processing, favorable welding performance and available corrosion resistance, and other characteristics. For special structure components in the actual production applications such as vessels and pipes, it inevitably involves the joining between nickel-based alloys and stainless steel. As an advanced welding method with high energy density, high cooling speed, narrow heat-affected zone, and low deformation and other advantages, laser welding is the gradual popularization and application for joining various kinds of materials including nickel-based alloys and stainless steels [4–8]. Especially, laser welding is increasingly recognized to joining dissimilar metals [9–11]. But so far, the microstructure and mechanical
properties of dissimilar welded Inconel 625 alloy and SUS304 stainless steel by high-power laser have been rarely reported. In the dissimilar welded metals, the focus has always been the microstructure of fusion boundary and element segregation in result from the melting of base metals and stirring of weld pool [12, 13]. On the other hand, it has been known that Laves phase is inevitably precipitated in the fusion zone of nickel-based alloys with high contents of Nb and Mo [14–17]. As an $A_2B$-type intermetallic phase (A: Ni, Cr, Fe and B: Nb, Mo, Ti), Laves phase is usually formed in the interdendritic regions during the solidification of laser welding process [18–20]. So in laser welding of Inconel 625 and SUS304, it is also worth to concern the potential problems of segregation of Nb and Mo.

**Table 1** Chemical composition of base metal (wt%)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Ni</th>
<th>C</th>
<th>Cr</th>
<th>S</th>
<th>Mn</th>
<th>Si</th>
<th>Mo</th>
<th>Ti</th>
<th>Nb</th>
<th>Fe</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconel 625</td>
<td>Bal.</td>
<td>0.02</td>
<td>22.1</td>
<td>0.001</td>
<td>0.05</td>
<td>0.09</td>
<td>9.2</td>
<td>0.18</td>
<td>3.45</td>
<td>4.6</td>
<td>0.14</td>
</tr>
<tr>
<td>SUS304</td>
<td>8.60</td>
<td>0.08</td>
<td>19.0</td>
<td>0.02</td>
<td>1.78</td>
<td>0.48</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Bal.</td>
<td>–</td>
</tr>
</tbody>
</table>

![Fig. 1](image_url)  
**Fig. 1** SEM micrographs of dissimilar weld metal in the upper weld (a), (b), (c), (d), (e) and (f) are different zones of the position I, respectively (electrolytically etched by 10% aqueous chromic acid solution)